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OCCUPATIONAL HEALTH REVIEW

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Industrial Health Centre
IN AN ATOMIC ENERGY PROJECT

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In 1953 a new Health Centre at the Chalk River Project of Atomic Energy of Canada Limited was completed. The purpose of this article is to describe and illustrate the facilities which were designed and provided. As a prelude it would be best to describe the work of the centre so that the basis for the ultimate design can be readily understood.

All new employees are sent to the Plant Hospital in the morning of their first day at the Plant. There they fill out a routine health questionnaire and undergo a complete physical examination, which includes such tests as a complete blood check, a urinalysis and a chest x-ray. In addition if such new employees are over the age of forty, a routine electrocardiogram is taken. These tests are repeated each year or more often if abnormalities are found. Because there is an extensive construction programme being carried on by outside firms, there are usually several hundred additional employees for whom medical care is provided and the total number of personnel is approximately two thousand.

In addition to routine examinations, the Health Centre provides care for minor injuries and illnesses and the staff is available for consultation, which may include further diagnostic tests and follow-ups.

Because of the hazards peculiar to an Atomic Energy Project, additional testing facilities are required. The workers in the active area are exposed to whole body radiation or the possibility of absorption of radioactive materials by the body. As a control measure more frequent blood tests are performed, the frequency depending on the degree of exposure. Furthermore, it has been found that the most sensitive monitor of laboratory working conditions so far as the control of spread of radioactive materials is concerned, is a routine analysis of urine for radioactivity. Such tests have added considerably to the laboratory space requirements of the health centre.

In spite of all precautions, accidents occur which lead to contamination of the body surface of workers. In most cases these are of a minor nature and can be dealt with in the special wash-up facilities provided in each laboratory building. But if this is not adequate the medical service is responsible for further decontamination procedures. This is especially true if the spill is a major one or if the spill is accompanied by other injuries causing open wounds.

All these considerations played a large part in the design which was finally chosen for the centre. Other factors were that some provision should be made for possible future expansion and that some space should be included for the bed care of patients. The necessity for this will be understood if one realizes that the nearest hospitals are in Deep River and Pembroke, twelve and thirty miles distant, respectively.

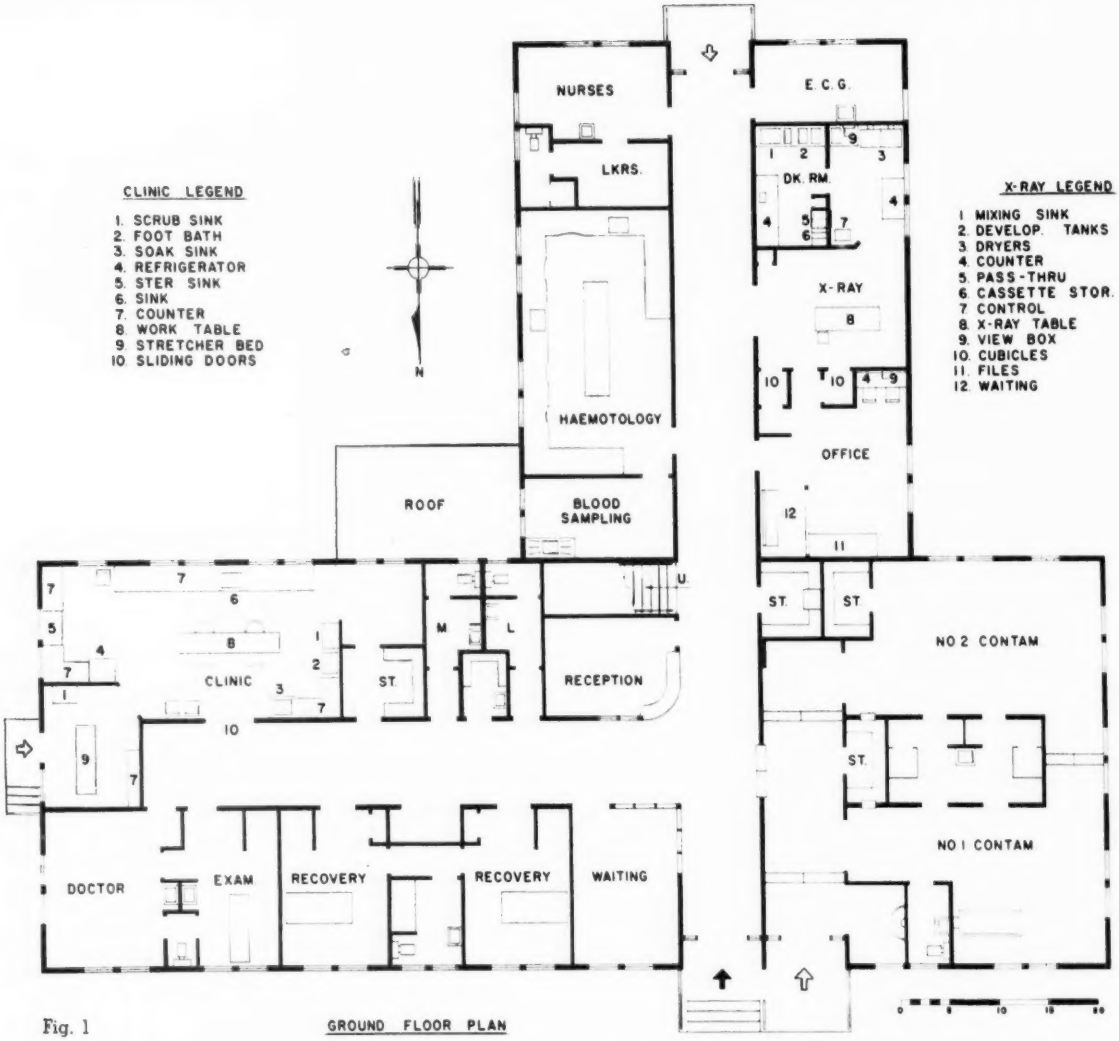

Fig. 1 GROUND FLOOR PLAN

The new Centre is a two-storey building which is located just inside the main gate of the Project. This location was chosen primarily because it is close to the Administrative and Personnel headquarters and to the Fire Hall, which houses the ambulance. An added advantage is that since all personnel pass the Centre each morning it is possible to arrange for routine tests, as required, with a minimum of interference with working hours.

The size of the Hospital was determined by the facilities required. Since, as already mentioned, they are greater than are normally required in an industrial plant of similar size, the floor area is proportionately larger. The first floor is given over to the main treatment facilities, and the general lay-out is as indicated in figure 1. On the second floor there are the laboratories where the urinalyses for radio-activity are performed. This floor is incomplete, and may be extended if additional space is required.

Fig. 2 Reception Desk

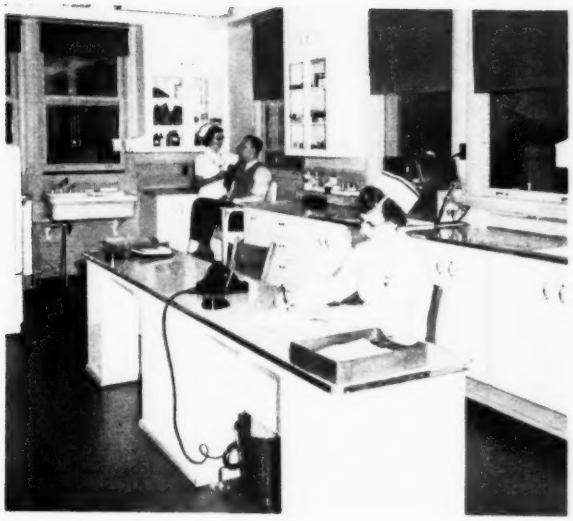

Fig. 3 Treatment Room

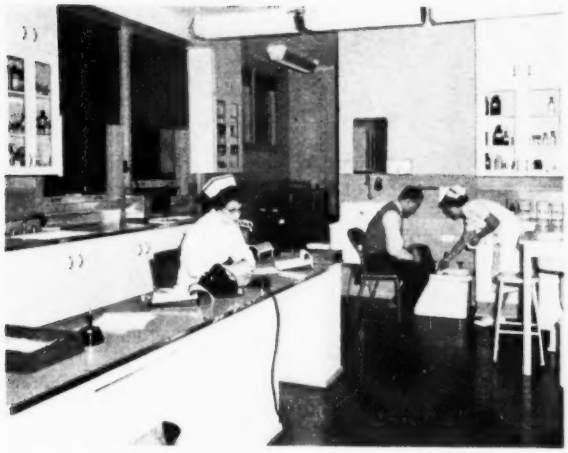

Fig. 4 Treatment Room

Fig. 5 Haematology Laboratory

It will be noticed that the main entrance is double, (title photo). One side leads directly to the decontamination centre, and is used only by contaminated personnel. The advantages of confining contamination to one area of the centre will be obvious to any who have faced the problem of decontaminating floors, walls, stretchers, taps, sinks, etc. Furthermore, since radioactive substances are far more dangerous when introduced into the body, they should be kept away from rooms where instruments and dressings are used in the treatment of uncontaminated wounds. And lastly, the successful detection of small amount of radioactive substances in urine requires that the laboratories themselves be free from any contamination. The decontamination centre which is divided into a dirty side and a clean side will be more fully described in a later article.

The main entrance to the treatment side which is wide enough to permit easy passage of stretchers, opens into the main lobby where there is a reception desk and a waiting room and where the flow of traffic may be directed down one corridor to the laboratory section, or down the other to the medical department, (figure 2). At the receptionist's desk the new employees fill out preliminary questionnaires before proceeding for medical examination or routine blood test, urinalyses, x-rays and cardiograms. An intercommunication system connecting the receptionist's desk, the physician's office, and the treatment room eliminates unnecessary walking. Patients are normally directed to the treatment room if reporting for medical care and then if necessary are referred by the nurse to the physician.

In the planning of the hospital it was decided that the corridors should be wide, that the colour used throughout should be light, and that the rooms should be brightly illuminated by artificial and natural light. It will be seen that the corridors are over eight feet wide. The upper part of the walls is a pastel green, while the doors and dados are greyish with a blue tint, and the floors covered with linoleum are buff-coloured in the corridors, and blue in the treatment rooms. This combination of colours has proved to be very pleasing and has created a cheerful atmosphere throughout the Centre, as well as making it easier to clean. To reduce noise, all rooms on the treatment side of the Centre have ceilings of acoustic tile.

Special attention was given to the design of the main treatment room. The views of this room are shown in figures 3 and 4. It will be noted that there are numerous windows and an abundance of lighting fixtures. The room is therefore well lighted at all times but the colours and finish of paint used on the walls and floors eliminate glare. The work desk faces the double doors opening to the room from the corridor. Because of its dimensions the room can be subdivided into working areas. A scrub sink, a low sink for foot baths, and a large sink for arm and hand baths are located at one end of the room. Patients requiring these treatments

are thereby removed from the main part of the room, and do not delay the treatment of other patients. Also, at this end of the room there is an alcove where clerical work can be carried out, and which leads to a small store room. At the opposite end of the room, ear, nose and throat ailments are treated. The entrance to the minor surgery room is also at this end. This surgery room is equipped with a simple operating table, a spot light and a scrub sink. Here minor surgical procedures and the removal of foreign bodies from eyes can be carried out. It is an advantage also to have such space for the more seriously injured workers.

As indicated, the physician's office and examining room are close to the treatment room. In addition, two rooms with a connecting bathroom were provided to serve as rest rooms, rooms where physiotherapy can be given, and as auxiliary examining rooms. At the same time they can be adapted for the holding of patients should this become necessary.

In the laboratory section, the haematology laboratory is provided with a separate room where blood samples can be taken and routine urinalysis can be performed. The only unusual feature about the laboratory itself is that the centre table is of concrete on a concrete pillar, so that balances and spectrophotometers are protected from vibrations, (figure 5)

Special attention was also given to the design of the x-ray facilities which are operated by a full-time technician. A small waiting room is provided which is separated from the main office containing a four-bank view box, the x-ray files and other records. From the office there is a corridor and two dressing cubicles leading to the x-ray room proper which is, of course, completely shielded by lead. The control panel is in the anteroom to the dark room. The dark room was built with no maze leading into it, but a pass through tank has been installed so that no one but the x-ray technician need enter the room, (figure 6)

Fig. 6 Dark Room, showing pass-through for films.

This centre has been in operation now for approximately six months and to date the staff has found no important defect in its design. This is in part due to a prolonged period of planning before construction was started, and was made easier by the staff's previous experience in the operation of a Health Service. The most important factor however, was that an opportunity was provided to design a completely new Health Centre, and no desirable feature had to be eliminated because of the size and dimensions of an older building.

Group Dynamics and Industrial Nursing

At an Institute for Industrial Nurses, held at the University of Ottawa, on September 24, 25, 26, 1953, Miss Mildred I. Walker, Senior Nursing Consultant of the Occupational Health Division, Department of National Health and Welfare, presented an outline of group dynamics and its application to the solution of challenges or problems confronting the industrial nurse. The principles of group dynamics, outlined by Miss Walker, were applied during practice group discussion at various times during the Institute, and the nurses responded whole heartedly.

Many of the challenges which were submitted on the first day of the Institute were later resolved by specialist speakers on the program, and those not resolved were brought up for discussion.

The primary object of these practice group dicussions was to acquaint the industrial nurses with proper procedure for formulation of challenges and conducting discussions intelligently and systematically, and to impress on them the necessity for flexibility in their thinking in order to deal with the wide range of challenges which might conceivably be encountered in the field of industrial nursing.

The second and more important objective was to encourage the industrial nurses to formulate their challenges properly, to seek a solution at the Institute, and, if a solution was not found, to ask for further assistance.

These requests are valuable agents for action from such agencies as Workmen's Compensation Boards, Provincial and Federal Occupational Health Divisions, and Universities.

It is an expression from those who give health services for Commerce and Industry, and indicates the acceptance of responsibilities in the industrial nurse's field of endeavour.

The Physiology of Work and INDUSTRIAL FATIGUE.*

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The physiology of work is a specialized branch of physiology which proposes to study the behaviour of the human body under the stress of work, and the condition under which it can operate with optimum efficiency (17).

The physiology of work has undergone a considerable impetus during the past few decades. It has sometimes been accused of being too theoretical. It is true that the majority of studies carried out by physiologists have been done under artificial conditions of the laboratory, and the type of work performed often greatly exceeds the standards of industrial work, and even involves purely theoretical studies on isolated organs, cells or enzymatic systems. However, such studies are important and necessary because they provide a better understanding of the scope and limitations of human work efficiency; they also indicate the difficulties and dangers to which the individual is exposed if the work performed is beyond the limits of his working capacity. Today, the physiologist willingly goes to the industrial plant and attempts to verify, under actual working conditions, the principles which he has evolved in his laboratories.

In this study, we propose to outline some aspects of the physiology of work with respect to its application to the problem of industrial fatigue. We shall attempt successively to define industrial fatigue, to specify its divisions, to outline its criteria, and finally, to discuss briefly some tests devised to detect it.

Definition

Although the term "fatigue" is familiar to all, its definition nevertheless remains difficult. Most of the authors even refrain from defining it and they take for granted that, since everybody knows what it is all about, it is useless to go any further. This attitude no doubt stems from the fact that the term is used to cover a great variety of conditions, each author applying the name to conditions encountered within his own field of interest.

For instance, for the physiologist who is working on a neuromuscular preparation, fatigue corresponds to a progressive decrease in efficiency of the isolated organ, caused by the decrease of nutritive reserves and an accumulation of the waste products. On the other hand, for the plant physician or the psychologist interested in the problem, fatigue is much more complex. However Sir Frederick Bartlett (1) has given a definition which is important to remember. "Fatigue is a term used to cover all those determinable changes in the expression of an activity which can be traced to the continuing exercise of that activity under its normal operational conditions, and which can be shown to lead, either immediately or after delay, to deterioration in the expression of that activity, or, more simply, to results within the activity that are not wanted."

It is seen however that such definitions concern objective fatigue, but completely neglect subjective fatigue such as is felt by the subject.

Subtleness of subjective fatigue as well as the variety of its modes of expression are undoubtedly due to its deep physiological meaning which, perhaps, has not been sufficiently emphasized.

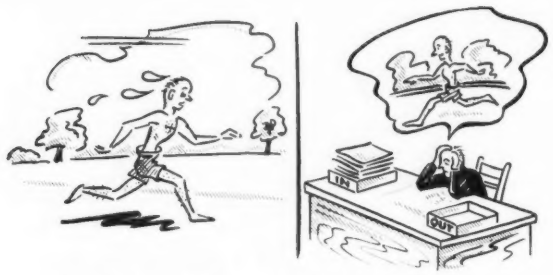
Subjective fatigue may be considered as an internal feeling which informs the individual that he is overworking—and here we use this expression in its broadest sense, to include muscular work as well as mental activity or emotional strain—and prompts him to rest by ceasing his work or changing his occupation. Thus considered as an internal feeling, fatigue may take on a mental aspect which, in borderline cases, makes analysis so delicate. We are aware that it may sometimes be as difficult to verify experimentally the statement of a workman who, in good faith, says that he is tired, as it would be to verify scientifically the statement of some one who says he is hungry.

This inner feeling is controlled mainly by the higher nervous centres and may very well be experienced before there are any clearly discernable blood alterations or physiological reactions of the cardio-respiratory system. Conversely, behaviour may be deeply altered without there appearing this special state which we commonly exteriorize by saying: "I am tired." (12).

Subdivision

It may be useful to subdivide fatigue, according to its origin, into muscular fatigue, and mental and sensorial fatigue.

* Paper read at the Annual Convention of the Association of Industrial Medicine of the Province of Quebec, October 1, 1953.
† Markle Scholar.



MUSCULAR FATIGUE MENTAL FATIGUE

Muscular Fatigue

Muscular fatigue, properly speaking, is certainly the most studied and better understood form of fatigue. From experiments on fatigue of isolated muscle and the Mosso ergograph to the numerous observations and experiments carried out on athletes and on persons subjected to various physical efforts such as forced marches, running on a treadmill, shovelling, and the step test, muscular effort has been explored in all its aspects.

However, such experiments have usually dealt with quite intensive muscular efforts, even leading to exhaustion. It is clear that such experimental conditions are rarely encountered in industrial plants.

A good indication of the importance of muscular work performed during the practice of a trade is the increase in the basal metabolic rate. As can be seen from Table I, work may be subdivided into light work, moderate work, hard or heavy work and maximum work. The basal metabolic rate increases two or three times for light work, from three to six times for moderate work, from six to eight times for hard work, and by over eight times for maximum work.

Hard work which increases metabolism up to eight times the basal rate is the maximum which can be maintained for eight hours. Beyond that, work may not be continued for any length of time without leading to exhaustion unless it is interrupted by frequent rest periods, which vary directly in time with the effort required to do the work and allow the body to recover from fatigue (7).

TABLE I

Classification of Work According to the Increase in the B.M.R.

Light work		**2–3 times the B.M.R.**
	Non-manual workers Sedentary, non-manual workers	
Moderate work		**3–6 times the B.M.R.**
	Tradesmen, tailors, cobblers, printers (linotype) precision metal workers.	
Intensive work (hard)		**6–8 times the B.M.R.**
	Metal workers, farm workers	
Maximum work		**Over 8 times the B.M.R.**
	Construction workers, miners, bunker-hands, woodsmen.	

If the increase of the basal metabolic rate is a good indication of work performed under normal conditions, work which may be called "light" or "moderate" could easily become exhausting under certain conditions involving for instance the use of relatively weak muscular groups, work which is predominantly static, work carried out in an abnormal posture, and, especially, work performed in the presence of heat (6).

Moderate and hard work are characterized by the fact that, after a fairly short start, the body establishes a equilibrium which will be maintained throughout the duration of work; the cardiac output and rate increase, the blood pressure rises, respiration increases in rhythm, there is an increase in the consumption of oxygen, and the body temperature rises (14). If the workman is well adjusted to his work and does not feel any undue fatigue, this level is maintained throughout the duration of the work. This physiological level may vary with the intensity of work and especially with environmental conditions. Cardiac rate is affected by temperature and humidity. The average cardiac rate during work is also an excellent indication of the intensity of the work performed and of the influence upon the body of the environmental conditions under which it is carried out. Christensen (6) has suggested figures (Table II) which appear to correspond with our own observations.

TABLE II

Variations in the Cardiac Rate According to the Intensity of the Work Performed.

Very light work	less than 75 min.
Light work	75 to 99 min.
Moderate work	100 to 124 min.
Heavy work	125 to 149 min.
Very heavy work	150 to 174 min.
Unduly heavy work	over 175 min.

(according to E. H. Christensen)

As an example, let us take the case of muscular work of relatively low intensity (3) in the presence of extensive radiant heat. The curve of cardiac recovery (fig. I) was plotted immediately after the task of removing, with a long handle rake, the fire-crust and burnt fire-sand from the inside walls of a furnace used in the manufacture of silicon carbide. This relatively light muscular exercise considerably overtaxes the body and becomes abnormally hard work; the cardiac rate reaches 192 per minute, with an abnormally prolonged recovery period since after twenty minutes of rest, the cardiac rate is still one hundred and eleven per minute.

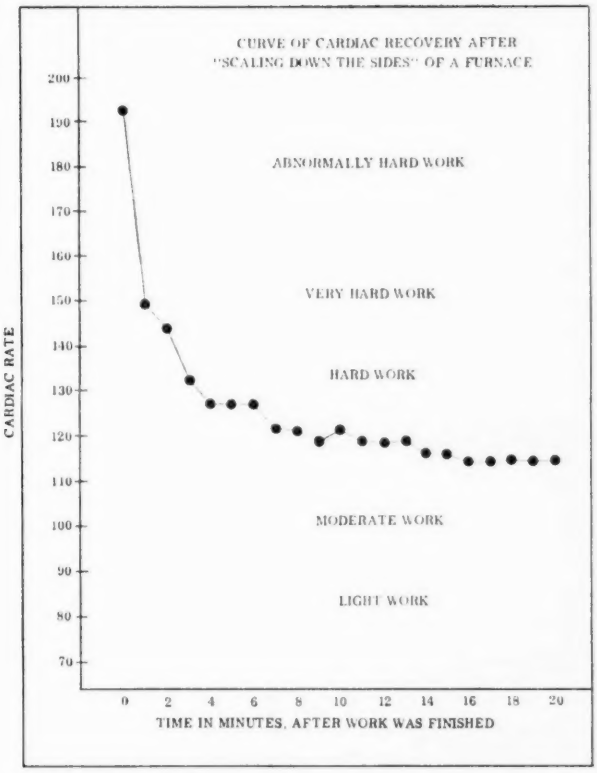


Fig. 1. Curve of cardiac recovery plotted after moderate muscular work performed near an important source of radiant heat.

As for maximum work, it is so intense that it cannot be continued for a normal working day, even under the best possible conditions. This type of work is not frequently encountered in industry. Here, no physiological level is possible and continuation of work may lead to exhaustion. The body is unable to dissipate its heat and there is a resulting hyperthermia; energy supplied by the diet is insufficient to sustain the body, body reserves are exhausted, and hypoglycemia may develop; under stress of great exertion, the heart is overworked and tachycardia may develop which may in turn lead to circulatory failure. Under such conditions of exhaustion the level of lactic acid in the blood stream rises because the body cannot manage to transform into glycogen the enormous quantities of lactic acid released into the muscle tissues. It can be understood then that the level of lactic acid in the blood is hardly a criterion of industrial fatigue. The present tendency is to consider it more as a criterion of cardio-vascular adjustment to work. (6)

What about fatigue in the great majority of industries which require only light to moderate work? In such circumstances the necessary physical effort which produces only slight physiological changes is relatively unimportant. There is only a relatively small increase in oxygen consumption, and a slight acceleration of the heart; blood changes are absent or negligible; lactic acid level, alkaline reserve, and hemoglobin are not altered. The food consumed by the workman supplies him with sufficient energy for his work, and consequently there is little strain on his reserves. Under these circumstances fatigue felt by the workman does not appear to be of a purely physical origin. Besides, workmen often derive rest from their work by engaging in a different type of activity often involving an expenditure of energy greater than that required by their work, *i.e.*, gardening, participation in exhausting games, or dancing. The term "boredom", frequently used to characterize this state of fatigue indicates the importance of psychological concomitants involved in this subjective fatigue which are not always easy to characterize objectively.

Consequently, this fatigue is not physical and involves factors of mental and psychological origin which may affect efficiency. Whitehead's experiment, reported by Dill (7) and several others reported since then, appear to demonstrate that, under favourable social and psychological conditions, both in the plant and outside, the working day may be spent in a pleasant manner and at a regular rhythm without fatigue or boredom.

Mental and Sensorial Fatigue

Mental fatigue is described as that fatigue which results from over-activity of the mind and of the sensory organs associated with it. This fatigue has a very definite psychological component, and, in the plant, it will be experienced by such people as executives who must often work long hours and assume heavy responsibilities. The man who can leave his work problems at the plant and have sufficient sleep and relaxation during his off-work hours will probably avoid this sort of fatigue, but the man who brings home his work problems and takes his home problems to work will undoubtedly feel tired most of the time.

S. A. Portis et al (19) have rightly reported that to this emotional strain are too frequently added very poor nutritional habits; hurried and insufficient breakfast, skimpy lunch, abuse of tobacco and alcohol. In a group of fifty young industrial executives, all under fifty years of age, who were investigated with respect to fatigue, these investigators found a relative hypoglyceamia in more than 40 per cent of the cases. They then suggested that, in addition to the periodical examination and advice concerning the organization of their life in order to reduce its emotional strain, it was frequently important to investigate further into their nutritional habits and to suggest a suitable diet (2).

Hearing fatigue is well-known. It is known that exposure to noise causes a reduction of hearing acuity which is the more pronounced and prolonged as the noise becomes more intense. (5) It has been shown that dry cotton wads moistened with mineral oil afford

a satisfactory protection (4). Recently it has been reported that in an important office, efficiency was increased, errors were reduced, and absenteeism and labour turn-over were lowered by decreasing the noise level from 75 to 50 decibels (18).

The Criteria of Fatigue

Three criteria for the detection of fatigue during the course of work have been established by Sir Frederick Bartlett. These are the initial criteria, the first two of which may be observed even before the subject feels any symptoms of fatigue.

In the first place, an increasing irregularity in the performance of successive phases of work is observed. This is solely an irregularity, a variation of the former rate, which may not change the overall rate of production over a period of time.

The second criterion involves a more important disturbance of the upper nervous centers evidenced by a lack of muscular co-ordination to a point where appropriate movements are made at the wrong time or important movements are omitted. It would appear that, either the individual's receptor mechanisms are not receiving properly the visual and tactile stimuli which normally promote the series of movements necessary to perform the operation, or that the reflexes which the stimuli condition are not functioning properly.

As his third criterion Bartlett uses the subjective signs of fatigue such as the feelings of weariness and exhaustion, and pains in the muscles.

One of the consequences of fatigue is therefore a rapid decrease in production rate and efficiency which may be evidenced in several ways. Gautrelet (10) suggests practical criteria which takes into account (*a*) the hourly production; (*b*) the rate of consumption of electric current by the machines when this current corresponds to the amount of work performed; (*c*) the number of spoiled parts especially in plants where small parts are made, and finally, (*d*) the frequency of industrial accidents. Numerous observations made during World War II when it was necessary to increase industrial production to the limit, showed that the number of rejects and the number of industrial accidents follow a parabolic curve when the 40-hour week is successively increased to 48, 54, and 66 hours (10).

Fatigue Tests

It would appear that there is no satisfactory test for the detection and the appreciation of the importance of subjective fatigue. However there are a great number of tests which, if selected with great care, may present an overall picture which can help us to draw satisfactory conclusions.

Let us note that in most disputed cases, where fatigue is involved, it is not so much a question of showing the existence of fatigue, (since fatigue is a normal consequence of work of any kind) but rather to discover whether this fatigue is abnormally great or simply to appreciate whether it is more important under one condition of work than under another. In other cases, where fatigue appears to impair production, it will be a question of seeking its cause and suggesting appropriate remedial action.

The study of a fatigue problem cannot, however, be limited to the use of any particular test. It requires an investigation of the workman and his physiological reactions, during and after working hours, as well as a careful study of conditions of work.

The worker himself is the first object of this investigation. Is he in good physical and psychological health? Indeed, it would be wrong to attribute to industrial fatigue the symptoms of tuberculosis, anaemia or any other disease. Are his eating habits satisfactory? He must supply the human machine with the necessary calories for the effort required, and in addition, the balance of his intake must be such that he is not deprived of any essential element. How does he occupy his free time? Does he get sufficient rest or does he spend his evenings or part of the night doing additional work such as bartending, taxi-driving or the like? Is he well adjusted to his work? Has he the morphological structure and the training suitable for the effort which is required of him? It is also important to know whether he is interested in his work, if he is ambitious, and whether his relations with his companions, his foreman and his employer are satisfactory, thus giving him a feeling of security. It must also be ascertained whether or not he brings his home worries, such as financial, marital, family, social or other problems, to the plant.

When we are satisfied that the worker himself is not the main cause of his fatigue, we can then approach the study of his reactions to work.

The observation most commonly used during work is undoubtedly that of the cardiac rate. We have seen that the cardiac rate rises rapidly at the beginning of work and reaches a level which must be sustained at least for work that is constant and continued. We have seen that a rise of the pulse rate above 150 indicates very hard work which can be maintained with difficulty while a rate above 175 indicates that the work is abnormally hard. On the other hand, if a pulse rate which, after a few hours of steady work rises above the level maintained up to that time, abnormal fatigue is indicated, showing that the body cannot maintain its physiological level. The interruption or completion of work is followed by a slowing down of the heart which will be delayed according to the intensity and the duration of the work. Curves of pulse recovery are difficult to interpret in an absolute manner, especially in borderline cases, but they become valuable instruments when it is a case of comparing the degree of fatigue among

groups of workers subjected to varying conditions of work.

The study of variations of the blood pressure may give similar information. The pressure rises slightly during muscular work and also reaches a level of adjustment.

An abnormal rise of blood pressure and, more important, a fall of pressure, indicate a defective adjustment to work, and loss of vascular tone is probably a very definite indication of fatigue. It is often difficult if not impossible to determine the blood pressure by the auscultatory method on account of the noise in the plant, but palpation gives excellent results. It is important however, to remember that this technique is satisfactory for the systolic pressure only, and that readings obtained are about 10 mm Hg lower than the values obtained by the auscultatory method.

The changes in lactic acid level in the blood have been discussed previously. Now let us consider the importance of urinalysis with respect to the Donaggio test.

The Donaggio reaction (8) is based on the theory that certain colloidal substances appear in the urine during fatigue, and that such substances are capable of inhibiting the precipitation of a thionin solution in the presence of ammonium molybdate. This reaction, which is positive after a game of football, a track meet, or a long swimming race, would indicate an increase in the permeability of renal capillaries (13). We have had an opportunity, on two occasions, to participate in investigations during which the reaction agreed both with the clinical observation, and with the results obtained by other tests used.

Although we realize that this test is still in the experimental stage, such results are encouraging and suggest new experiments. This test gives results much earlier than the titration of lactic acid, and would permit the detection of fatigue even before it is felt by the individual (11).

In plants where the worker is exposed to heat, the body temperature and loss of water from the body should be checked. According to Christensen (6) the highest desirable rectal temperature is 38° C. (100.4° F) and the highest temperature which can be tolerated by the worker exposed to heat is 30° C. (102.2° F). Wartime studies carried out on troops during forced marches in the tropics (15) have shown the importance of the loss of water through perspiration, both visible and insensible. The loss of salt through perspiration is also of importance. During a recent investigation (3) we found that the loss of water suffered by workers exposed to the heat of furnaces could reach averages varying from 8.51 to 11.68 pounds of water, *i.e.*, water losses equivalent to 5.7 and 7.8 percent respectively, of body weight for an average weight of 150 pounds. (fig. 2).

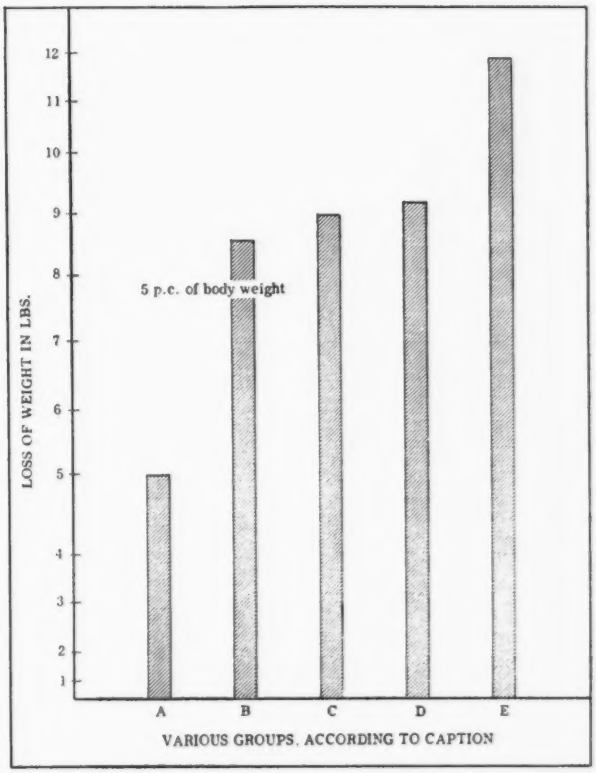


Fig. 2. Loss of weight suffered during the working period, during the hot days of the summer.
Caption: A: Control-Yard men
B: Teams of 7 men tending large furnaces
C: Teams of five men tending large furnaces
D: Teams of five men tending small furnaces
E: Teams of four men tending small furnaces.

These important water losses, especially in the latter case (7.8 per cent) are quite capable of reducing resistance to effort and of rapidly causing symptoms of fatigue.

Several other tests are used to discover fatigue and to appreciate its importance. Such tests include flicker fusion frequency, the search for reaction times, attention tests, co-ordination of movements such as the Mac-Quarrie tests, and tremor tests (9). Most of these are still in the experimental stage, but they make a very definite contribution to the study of fatigue.

An investigation into industrial fatigue would not be complete without a study of employee working conditions with the principal aim of discovering the predisposing causes or circumstances which promote fatigue and also of instigating changes designed to improve efficiency. Here, many points must be taken into account. Let us outline only the main points: atmospheric conditions; the concentration of dusts and toxic substances; lighting; noise; monotony; the attitude of the worker towards his work; the machines themselves; the ease of access to their vital parts and operating levers; health

facilities; eating facilities; possible sources of accidents, etc.

Time and motion studies are playing an increasingly important part in the determination of standards required for workmen. Such investigations are usually very well conducted and provide for everything, even for necessary rest periods during the course of work. But this great precision may become suspect when it is no longer applied to machines, but to men whose nerve relays and movement co-ordination are not as predictable as those of a mechanical gear train. The critical point of such job studies lies undoubtedly in the importance of the rest periods allowed during the course of work. If in the majority of cases, the percentage allowed is satisfactory, when the work becomes very heavy or maximum, rest periods must increase in geometrical progression according to the intensity of work and in such situations we frequently observe that the estimated rest period is insufficient.

Altogether, the problem of industrial fatigue has multiple aspects. We have seen that it is important to discriminate between subjective fatigue and objective fatigue since there is no necessary correlation between the two. The length of the rest period must be increased in geometric proportion to the increase in effort required to perform the work. As yet no satisfactory test has been devised which will give us a fatigue index or show us in a precise manner the moment when physiological fatigue, which necessarily accompanies any work, becomes pathological. However, the clinical study of the worker at work, which includes reactions during and after work, the study of his cardio-respiratory adjustment, the analysis of the malfunctioning of his reflexes, the investigation of co-ordination of movements and reactions times and other tests which we have mentioned during this study, supply an overall picture which permits us, more often than not, to draw conclusions which appear quite satisfactory to us.

Finally, let us not forget that the human machine cannot be as rigidly accurate as a mechanical device; that it is liable to fail, to stop or to slow down due not only to the muscular effort required and the conditions under which the work must be performed, but also to all the worries and problems which the worker brings with him to the plant which are liable to impair his efficiency greatly.

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Considerations of Foot Injuries*

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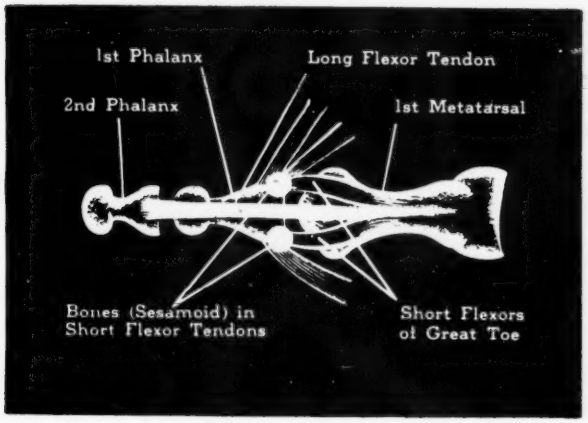
The human foot is a complex structure designed to support the body in an upright position, to afford balance and to provide locomotion. The skeletal structure of the foot comprises several small bones which articulate with each other and are held together by tendons, muscles and ligaments. The whole structure is covered with connective tissue and skin.



These anatomical components are arranged in such a manner that the body weight is equally distributed over three main points on the foot, namely, the heel, and the heads of the first and fifth metatarsals. If an injury to the foot results in body balance being disturbed, marked incapacitation for work, and considerable discomfort may result.

Foot injuries may be conveniently classified as wounds, contusions, fractures, or any combination of these.

Wounds

Superficial wounds of the dorsal aspect of the foot may involve the skin, the extensor tendons of the toes, as well as the nerves and blood vessels.

Hence, debridement of all wounds of that type must be performed to ascertain the extent of the injury. Such wounds should not be closed before a thorough exploration has been carried out.

Vessels must be ligated and nerves and tendons sutured. Regardless of the extent of the wound, the surgeon must take the strictly conservative view and resect nothing, for a loss of skin always results in important sequelae.

For deep wounds involving the bony structure and joints, treatment is the same as for fractures.

Superficial wounds of the plantar area are treated like those of the dorsal aspect.

Deep wounds require full exploration and adequate care, since several muscles, blood vessels, and important nerves may be involved.

It must never be forgotten that the skin of the plantar area is specialized structure and therefore should be saved at all costs; satisfactory results are not always achieved in injuries necessitating skin graft.

Contusions

Contusions may prove most serious if they result in gangrene of the skin and tendons, or if they are accompanied by fracture of foot bones. Radiological examination is indicated because considerable incapacitation can result from the smallest fracture involving a joint.

Slight contusions may produce neurovascular complications resulting in extensive decalcification which may render a man completely unfit for work.

Severe contusions may cause considerable tearing of the plantar aponeurosis, and produce marked changes in the balance of the foot.

Fractures

Closed fractures of the toes should first be reduced and later immobilized in a plaster cast. The current policy is to wait for any swelling to subside and then to apply a small plaster cast. The cast should be fitted to the contours of the toe to provide better retention of the fracture. Casts are more practical than wood or metal splints, because they allow the patient to continue to walk and work.

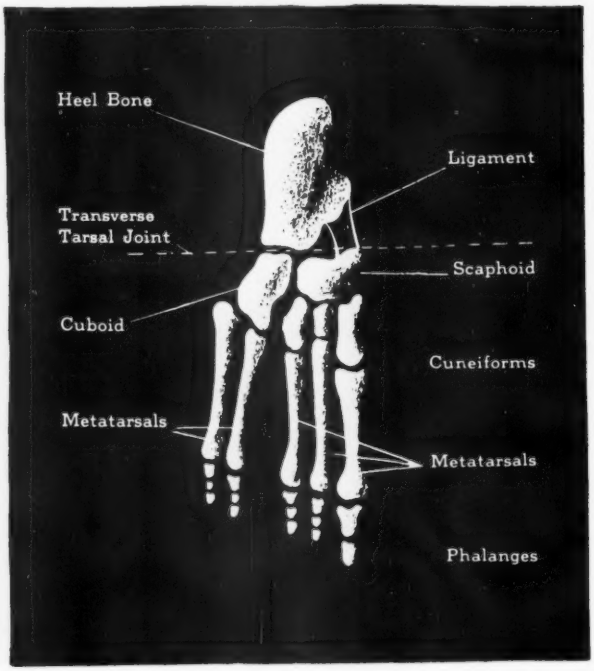
Open wounds should be excised and the skin sutured before the fracture is set.

In the reduction of fractures of the metatarsals, greater attention should be paid to the normal contours of the foot than to anatomical reduction because the

* Adapted from a paper presented at the Annual Convention of the Association of Industrial Medicine of the Province of Quebec, October 1, 1953.

latter is difficult, and frequently necessitates open reduction, a method of treatment best avoided in such fractures, except when specially indicated.

Fractures of the cuneiforms, the scaphoid and cuboid, must be reduced perfectly because these bones have multiple joint surfaces and form the vault of the plantar arch. They therefore require careful anatomical reduction to avoid serious incapacity.



Fractures of the astragalus must be treated in a similar manner, because its joint surfaces are responsible for the principle movements of the foot.

Fractures of the os calcis are serious, because the greater part of the body weight rests on this bone. They are to be divided into two categories:

1. Non-articular fractures;
2. Articular fractures.

In fractures not affecting the joint surfaces between the os calcis and the astragalus, reduction should first be carried out followed by immobilization until complete union has occurred.

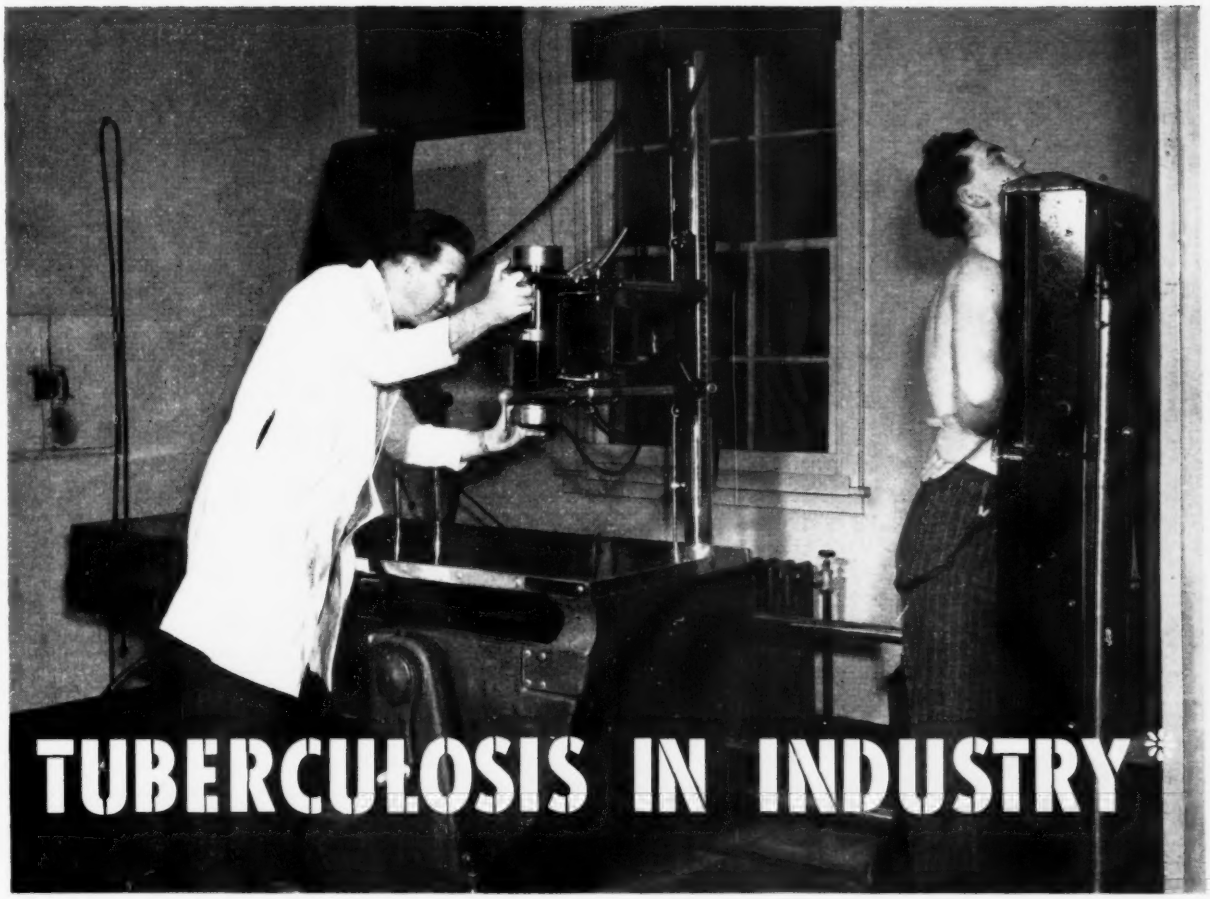
When articular surfaces are involved, reduction must be perfect; otherwise open reduction may be necessary.

In multiple articular fractures associated with serious injuries of the joint cartilages, astragalo-calcaneal arthrodesis should preferably be performed at once, in order to shorten the period of temporary incapacity. Otherwise, that procedure has to be resorted to in the majority of cases, five or six months after the accident, and the complete temporary incapacity period is thereby lengthened.

In fractures of the tibio-tarsal joint, anatomical reduction is required. Such fractures are usually reduced easily enough without recourse to open reduction, except in a few special cases.

Dislocations of the foot must be reduced carefully, particularly those occurring at the level of the cuneiforms and of the metatarsals.

These are rather brief comments on foot injuries prepared with the sole purpose of calling the attention of doctors engaged in industrial medicine to the importance of the feet and suggesting practical methods of treatment, in the light of our present experience. The opinions expressed are personal and, therefore questionable.



TUBERCULOSIS IN INDUSTRY*

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A few years ago, I had the opportunity to discuss before this Association the death rate from tuberculosis in industry in general. At that time we compared this death rate from tuberculosis with that found in the general population and we came to the conclusion that the industrial worker enjoyed a favourable situation, especially in those companies with adequately organized medical services. This picture is further improved so that now the morbidity rate from tuberculosis in industry is approximately one in one thousand.

The next objective to achieve in control of tuberculosis would be the complete elimination of this disease; however, since this disease is contagious, the worker, who spends about two thirds of his life outside company's grounds, may become infected during his off-work hours, through contact with untreated tuberculosis patients in his home and social environment, in spite of every preventive measure taken by the industry. Therefore, let us consider what precautions should be taken both at the pre-employment stage and during periodic medical examinations to ensure maximum protection.

At the pre-employment examination a candidate must obviously be free of any active tuberculosis. To be sure of this all new employees should be given a tuberculin test—that is a patch test, the Mantoux test or the so-called B.C.G. test. Either a negative or a positive reaction will be obtained.

Individuals with a negative reaction to the test used should be tested every year thereafter to see if there has been any change in reaction. A change in reaction to positive will indicate that the employee has developed a primary infection. This may show up on the X-rays as a pulmonary focus associated with a hilar adenopathy. Subjective symptoms may be absent or they may sometimes be evidenced in the form of fatigue or slight emaciation. If only a hilar or intra-pulmonary calcification shows on the X-ray film, the condition should be under control in a few months.

Unfortunately, for some reason or other, some employees at this important stage of their life, find their strength decreased either through a concomitant disease

* Paper presented at the Annual Convention of the Province of Quebec Industrial Medical Association, October 1953.

or from overwork, so that instead of a mere vaccination as usually seen, more dramatic changes will take place. A serofibrinous pleurisy, erythema nodosum, peritonitis, or less often meningitis will indicate tuberculous infection. A few months ago, we had a case illustrating the above situation.

A nineteen year old worker, employed by a company for nearly three years, had a normal X-ray at preemployment examination, and his annual or periodical X-rays were also negative. Four months after his last examination, he developed influenza, then serofibrinous pleurisy; a skin test was strongly positive. On account of the family history of this employee, we sent him to a sanatorium. Rigorous therapy was instituted and was well followed by our patient. Three months following his admission, he developed tuberculous meningitis and, notwithstanding the use of every known antibiotic, administered by all possible routes, he died from tuberculous meningitis seven months after his admission to the sanatorium.

Positive reacting subjects should be thoroughly questioned concerning: (1) their family history, particularly with respect to the possibility of tuberculous cases in the family; (2) their personal history which may indicate the nature of the tuberculous disorder which they had developed in the past.

A skin test must be supplemented by a chest X-Ray for every new employee. It will then be possible to detect not only pulmonary lesions, but also several other important abnormalities of the thorax, pleura, mediastinum and heart. The chest X-ray report should be accepted in the sense intended by the radiologist; the latter can merely interpret a shadow, so that in abnormal cases, the X-ray report should always be supplemented with clinical and laboratory examinations, in order to evaluate the importance of any abnormal X-ray findings. Pleural sequelae, irregularities of the diaphragm and rib deformities are of little importance, although such scars may account for certain chest pain.

Calcified nodules, single or in small numbers with well defined outlines and uniform density, are not a contraindication for employment. On the other hand, tuberculomas should be closely watched, and it must be firmly established that such a density has been inactive for several years, and that laboratory tests are negative for tubercle bacillus, following culture and even guinea pig inoculation. Some American authors advise segmental resection in order to prevent a tuberculoma from softening.

Subjects showing non-tuberculous bronchial dilations of congenital or acquired origin should have special consideration, since they are subject to pulmonary or cardiac complications. Individuals who have suffered serofibrinous pleurisy in the twelve months previous to the examination in question cannot be accepted. This opinion is based on statistics of the Armed Forces, which show that nearly 40% of our men who had suffered serofibrinous pleurisy had to be hospitalized in the five subsequent years for tuberculous pulmonary affections.

In connection with this, insurance companies who have established their policies on their own statistics, impose a delay of five years following a serofibrinous pleurisy, before accepting a candidate at standard rates.

Hilar enlargements may be caused by an infection of the upper respiratory tract, but they are mostly due to tuberculous adenitis, tumours of lymphatic origin or pneumoconiosis.

Any candidate showing pulmonary tumours on X-ray examination should be referred to a chest clinic where proper action will be decided on. Should such a candidate have undergone surgical treatment, only a report from the pathologist establishing the fact that the original tumor is of a benign nature will justify us in accepting such an employee.

A radiologist's report of deformities of the cardiac or aortic outline should be considered very carefully.

We have intentionally reserved until last consideration of those individuals with treated or healed tuberculous lesions. Certain jobs are obviously inconsistent

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ICELAND ON THE PRAIRIES. Technician Mrs. Unnur Watson, who handles 200 x-ray plates daily at the Winnipeg Clinic, is one of 4,000 members of Winnipeg's Icelandic community.

with the reduced resistance of such individuals. On the other hand, it is our duty not to reject these candidates systematically, because this would be anti-social and antiscientific. Such individuals have the right to demand of society that they be provided with employment, so that they may earn a living and not be considered as outcasts of society. This group of individuals will not secure readjustment to a normal life to which they are entitled if they have to rely on other companies or charity. At present, everybody fears Communism; therefore, let us not prepare grounds which might be favourable to its development.

I readily agree that company management is not willing to employ useless individuals because it does not consider its firm as a benevolent agency; therefore, it is the physician's duty to prove to management that the hiring of former tuberculous patients involves no hazard, provided that the following conditions are met:

1. That such individuals have been authorized by a physician or an organization specializing in tuberculosis, to perform some definite work and that this same specialized organization will provide for the follow-up of such persons.
2. That the work be within the physical capabilities of the individual.

Moreover, statistics show that such former patients appreciate the advantage of paid work, and the fact that they generally do their utmost to provide satisfactory service for their employers makes them an asset to the companies employing them.

A pre-employment skin test and X-ray, with supplementary reports in doubtful cases, will provide every possible precaution necessary to prevent tuberculosis from invading our industries through new employees.

However, such protection must be continued to the employees at work. We have a record of all those cases of tuberculosis which have developed among our employees and the financial problem is tremendous for both the employee and the employer. The problem of replacing these employees for periods varying from 18 to 24 months, sickness insurance, pension fund, assistance to the patients' families and, finally, that of readjusting such employees to their work makes tuberculosis one of the most costly diseases for a company.

We feel that a few suggestions would be in order if this situation is to be controlled:

1. All employees showing a negative skin test at the time of hiring should be retested every year and, as previously noted, those showing a positive reaction should be closely followed up.
2. A system of annual chest X-rays is to be recommended, but it is still more important to establish, at the time of hiring, a classification which will indicate when the next X-ray should be taken. Such a classification should be based on the type of work, age and past history of each employee. The term —"type of work"— could be interpreted in my opinion, with respect to salary. It was proven, several years ago, that tuberculosis claimed most of its victims from among day labourers; the specialized worker earning a high salary can afford better living conditions and benefits of a better balanced diet and is thus less likely to contract the disease.

The period of 20 – 35 years of age still remains most favourable for the development of tuberculosis, because during this period individuals tend to subject themselves to greater stresses of every kind, both in the way of work and amusement; such stresses correspondingly reduce the resistance of the individual.

Family and personal past history also provides valuable information concerning the development of tuberculosis.

A card index should be used to ensure that every employee reports for a chest X-ray on the day agreed upon.

3. Any employee absent from work for 15 days or

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CHARLES CAMSELL INDIAN HOSPITAL, EDMONTON, ALBERTA. — Thoracoplasty, Charles Camsell Indian Hospital, Edmonton, Alberta.

more from any pulmonary affection should be X-rayed before returning to work.

4. It is extremely important that the employee be educated in the question of tuberculosis prevention, making use of all means at our disposal. For instance, when reporting on a periodical chest X-ray, the need for a chest X-ray of the employee's family might be emphasized, keeping in mind that the employee spends only eight hours on the company's premises and 16 hours at home and, therefore, he should ensure the same protection at home that he gets at work.

For almost ten years every Canadian industry of importance has been visited periodically by mobile X-ray teams. The intelligent co-operation extended by plant management and labour unions has impressed employees with the importance and advantages of such X-rays, and they now recognize the need for them. The weak point of this system is the negligence of the family of the employee and of the general public in availing themselves of this opportunity when offered to them. The fact that all employees of a company have submitted to a chest X-ray does not mean that effective protection against tuberculosis is established in their homes and social environment. The essential complement to such a radiological survey is that any employee showing any abnormal images should submit to further examination by a chest clinic or a tuberculosis specialist.

No one should be satisfied with a mere medical report; he should have proof that laboratory tests have been made. One should be on guard against so-called compassionate certificates which unfortunately some of our colleagues grant too freely. At this point, I wish to draw your attention to abnormal shadows, apparently fibrous or so-called healed; in such cases, it is a good precaution to have at least three sputum cultures performed, otherwise we shall risk overlooking an active lesion undetectable by X-ray, or apparently calcified.

In Montreal, recently, the Health Department set up an organization which, today, appears to be the ideal system for winning the co-operation of all these families which may draw some benefits from chest radiography.

According to a plan which will be extended over several years, all school children will be submitted to a tuberculin test; those showing a negative reaction will be vaccinated with B.C.G. while those showing a positive reaction will be X-rayed. In the latter cases, their families will be invited to have similar examinations. The interesting point of this experiment is that parents who have seen positive reactions on their children's skin, have called at the T.B. Clinic, requesting an explanation of the reaction and asking for X-rays. This situation is very important, since the fear of tuberculosis is the beginning of its elimination.

Before concluding, it would be advisable to insist on the need for you to return former employees to their old jobs after discharge from the sanatorium, on condition that their discharge is authorized by a responsible physician and that they remain under the supervision of an experienced phthisiologist. Our moral responsibility to provide such individuals with a means of living is in this case still greater than at pre-employment, and there is no reason why we could not find for those individuals some type of work suited to their condition. To find work suited to the strength of the individual is a personal problem, and it is impossible to establish a classification exactly covering every former patient. When a phthisiologist is requested by a company physician to give his opinion in recommending an employee, he must base his judgment on two factors: the patient and the job.

During his illness, the tuberculous patient suffers a series of pathological forms of tuberculosis which affect his system to a greater or lesser degree. For instance, a small congestive lesion, which has quickly yielded to treatment, will not have the same influence on the patient's future as lesions which cavitate and ulcerate, heal only after months or years of treatment and collapse therapy, and often with alternating extension and regression.

The employee's personality should also be taken into consideration and the treating physician who has been in contact with this patient during 18 to 24 months, is aware of the former's disposition, as well as his moral values and in particular his ability and desire to carry out treatment routines. Therefore, it is of prime importance that the employee know exactly what type of work is planned for him. This will allow the phthisiologist to avoid using the terms "authorize light work", a much too lax formula, since it often has different meanings in the mind of the treating physician, in that of the patient who is too anxious to be accepted, and in that of the foreman who is required to keep up production.

In brief, in order to achieve control of tuberculosis in industry, the following requirements should be met:

1. A serious pre-placement examination, taking into account the personal and family past history of the candidate; the use of the skin test and a chest X-ray are imperative.
2. The interpretation of any abnormal lung picture with due allowance for clinical and laboratory conclusions.
3. Periodical chest X-ray will be based on age, type of work and tuberculin tests.
4. Any employee developing a pulmonary illness while at work should be X-rayed before resuming his work.
5. The education of the employee's family and environment constitutes a highly significant factor in the control of tuberculosis in industry, because this particular source provides most of the new cases of tuberculosis among our employees.

Rehabilitation in Industry*

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The employee who has been disabled either through accident or sickness has been a major problem in industry for many years.

Before the advent of compensation laws and company sickness insurance plans, the welfare of the disabled was not considered to be the employer's responsibility, but during the last few decades, it has gradually become one of industry's problems. The increased operating tempo of business and manufacturing have necessitated a corresponding acceleration of human living, with the result that we are constantly driving ourselves to further effort.

Norman Vincent Peale, Doctor of Divinity, in his book "The Power of Positive Thinking" states, "People are so keyed up nowadays that, I, a Minister, must report that it is almost impossible to put them to sleep with a sermon—it has been years since I have seen anyone sleep in Church, and that is a bad situation."

Industry is suffering the impact of this accelerated rate of living in the form of increased accidents and illnesses, and is putting forth considerable effort to improve the situation.

Safety engineers, safety committees, preventive medicine and surgical procedures all have contributed substantially to the prevention and treatment of accidents and sickness. They are proving that literally nothing is impossible when proper rehabilitation, training, counselling and selective placement are carried out.

Production in all our industries has been speeded-up to such a degree that the employees who attend the machinery of production must be on the alert every minute of their tour of duty. The man supervising the job must strive to the utmost of his ability to keep the production-line intact and the quantity and quality of production up to, or above, standard. Management must assume the costs, so that the wheels of industry turning ever faster effect every phase of life.

Statistics indicate that the normal span of life has increased. This would seem to be a paradox, but no doubt might be accounted for by the advances in the medical profession. Research in industry and medicine has reached magnitudes never before dreamed of.

The problem of maintaining production necessitates a high degree of efficiency of both worker and machine and for this reason accidents must be kept to a minimum and health maintained at its maximum.

Since we have established the fact that the increase in operating tempo of business and industry is responsible for an increase in the number of accidents and illnesses, a decrease in tempo would appear to be a logical solution. But the expanding economy of our country has necessitated this increase in speed, and any slowing down would seriously hinder progress. Therefore, it is essential that the human machine keep pace with commercial and industrial development.

Laws have been passed to compensate the injured for loss of time and for permanent disabilities, but there is no law to pick the job for the man, or the man for the job, except that oldest of all laws, "The survival of the fittest". Almost all large industries now have medical departments where the man receives pre-employment and periodic routine medical examinations. Some industries employ psychologists who pick the man for the job, surgeons who keep the disabilities to a minimum, and psychiatrists to assist in the solution of employee's emotional problems. In spite of all precautions we still have the disabled, and the disabled have their problems. Industry needs them; they need industry.

Our problem then is to prevent accidents and sickness, to shorten the period of disability, and to rehabilitate the disabled. This problem is everybody's problem whether he be in industry, or not, so let us start

*Paper presented at the Annual Convention of the Province of Quebec Industrial Medical Association, October 1953.

with the injured or sick employee. It is to his own advantage to remain healthy and avoid accidents, and if he becomes a victim of either accident or illness he should do all he can to rehabilitate himself. He must have the desire to do so, and very often he will need help to overcome difficulties which may be within himself, or may be due to factors beyond his control. Some psychological upset may amount to a slight emotional disturbance, or may be sufficiently severe to cause loss of self-confidence. Here, an effort must be directed towards maintaining emotional stability and boosting morale.

In recent years medical social workers have played an important role in helping to solve some of these social difficulties. They visit the home and meet the family, and can be of great assistance to the attending physician, surgeon or psychiatrist. The professional social worker is trained to help the individual to work out problems of social adjustment, and to develop an insight into his difficulties and their causes. She may help those who are capable of self-direction to think through some of their troubles and work out a satisfactory solution.

Social workers are usually paid by some organization not directly connected with industry. Their salaries are to a very large extent met by public subscriptions and endowments, unless they are Government employees. Industry would benefit a great deal by investigating this field in more detail, and by availing themselves of the service of social workers specially trained for industrial work. The psychologist plays an important part in industry and although the social worker cannot take his place she can be of great assistance to him.

When an employee is absent from his job and does not report, some investigation is usually carried out by someone from the employment department. The employee may be incapacitated by an accident outside the plant; he may be suffering from an illness; he may be interested in some other personal business; or his sickness may be due to alcoholism, or many other causes. It is not the duty of the medical department to investigate and report the cause of his absence. A social worker who can enter the employee's home and help with his problems or show him how he may solve them himself, is more likely to achieve results which are satisfactory to the man, to his family, and to his employer. Socially, the patient's family, his friends and environment may require almost as much adjustment as the patient himself. The social worker is trained to make these adjustments, not necessarily by herself, but with the help of other agencies.

So everybody concerned is trying to help the disabled. Now the man has had his wounds healed, or his sickness cured, and he is ready and willing to work. He has had medical, surgical and social aid—the best procurable,—but he still has a disability. He has lost a leg, an arm, or is partially incapacitated from some cardio-vascular, renal or nervous disorder. He cannot return to his former job, but he wants to work. Now, who takes the responsibility? Companies as a rule, are very humane and often will find work of some kind, but they are not legally responsible. They pay their dues to the Compensation Commission and the employee receives his compensation, or if he is partially disabled by some sickness which is non-compensable, he receives no remuneration, unless he carries some sickness insurance, either through a company plan or on his own volition. If he has no insurance he has to depend on his friends or charity. If the company has no suitable job for him he becomes a charitable case.

In such instances, social workers may be very helpful. They make a thorough investigation of the disabled person's financial condition, and as they are in constant touch with the charitable institutions, they may obtain the necessary assistance for the unfortunate individual until suitable employment is found, provided that he is not totally disabled. His future possibilities will depend largely on his desire to rehabilitate himself. Opportunities, however, are influenced by factors other than the individual's desire to work, and here the social worker may be of considerable assistance. She may refer him to a voluntary rehabilitation centre in the community where he may be kept for a period of observation. Then if he is found suitable, he may be given a course of training which will equip him for skilled work commensurate with his aptitudes, and within his physical capabilities.

I have endeavoured to cover this field of rehabilitation in a very general way. Methods of prevention of accidents and sickness, treatment of the patient, medically and surgically, with the recent advances in surgical techniques, and in therapeutics, have not been dealt with. The purpose here has been to emphasize the need for a close contact between the personal factors of the disabled and the rehabilitation services.

The physically impaired are human beings. Their opportunity for further usefulness to themselves, to their families, and to mankind is our problem. We should encourage the industrial social worker, whose professional aims are to solve the problem of the disabled and to develop and improve services for the total rehabilitation of individuals with permanent physical disabilities.

Occupational Health

RESEARCH PROJECTS

Occupational Health Division, Department of National Health & Welfare,
Ottawa, Ontario.

Turbomist Sprayer

Since World War II, organic insecticides have largely replaced the inorganic compounds formerly used in Canada and the United States. Although these newer insecticides have been found to be more effective for the control of insects, they represent a potential health hazard to manufacturers, sprayers, and consumers unless the most rigid safety precautions are adhered to. For this reason they should not be used to control insects attacking man or animals, nor should they be used in households, storage rooms, and similar places.

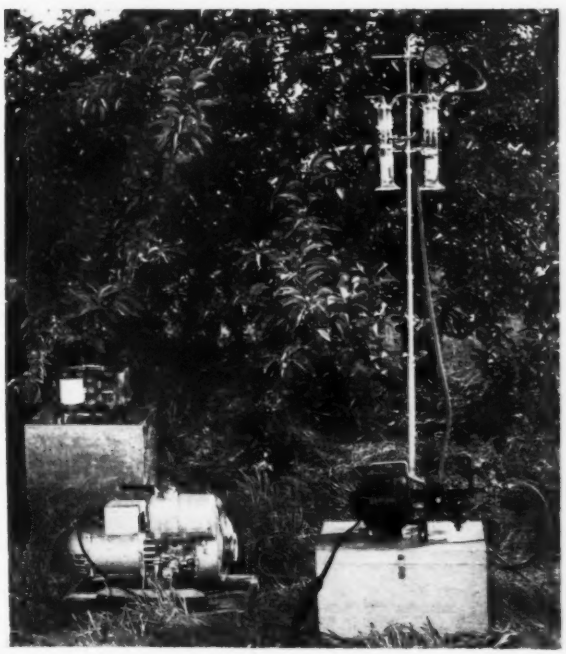
The organic phosphates, compounds closely akin to the deadly nerve gases, are among the most popular of the newer organic insecticides currently in use. One compound of this group, diethylparanitrophenylthiophosphate (commonly called parathion) has been used in Canada as a fruit and vegetable spray for the past few years.

Physiologically the organic phosphates inhibit the action of the enzyme cholinesterase and signs and symptoms of toxic effects are similar to those produced by muscarine, nicotine and pilocarpine. Modes of entry into the body are by inhalation, ingestion and skin absorption.

Cholinesterase changes are calculated indirectly from the rate of destruction of acetylcholine which has been added to samples of red blood cells and plasma. Cholinesterase levels are expressed in terms of percentage of normal, each individual acting as his own control because there is considerable variation in the normal value from person to person.

In co-operation with technical personnel from the Province of Quebec, Division of Industrial Hygiene, members of the Occupational Health Division, Department of National Health and Welfare conducted studies in certain Quebec apple orchards during the summers of 1951, 1952 and 1953, to determine the relationship between parathion exposure and cholinesterase response of spray operators. The 1951 study was published in the A.M.A. Archives of Industrial Hygiene and Occupational Medicine September 1952, and reprinted in the Industrial (now Occupational) Health Review, October 1952, but the 1952 and 1953 studies are as yet unpublished.

As part of the 1952 Quebec apple orchard investigation, a study of parathion spray concentrations and air and leaf residuals was conducted in certain Quebec orchards by members of the Occupational Health Division Laboratory, and the following are summaries of this, and two other studies carried out during the same summer.



Air Sampling Apparatus

Study No. 1—Parathion Spray Concentration and Air and Leaf Residuals in Quebec Apple Orchards

As part of the field study of parathion exposure and cholinesterase response of Quebec apple growers,

samples of spray mist were taken during spraying operations, and leaf and air samples were taken subsequently. These studies were carried out in orchards where concentrate sprayers were used and they supplement data obtained for dilute spray methods during the summer of 1951.

The sprays used were 1.5 pounds (dilute) to 4 pounds (concentrated) of 15% parathion wettable powder per 100 gallons of water applied at rates varying from 1.5 to 10 gallons per tree by Myers Concentrate, Turbomist and Hurst Conversion Sprayers.

Spray Samples

During spraying operations, samples of spray mist were taken in the operator's breathing zone and analyzed by the method of Hirt and Gisclard.

Average concentrations of parathion in air samples ranged from 0.30 micrograms to 0.52 micrograms per litre. Although these values are below those previously reported, they are still three to five times the accepted threshold limit concentration of parathion in air, which has been set at 0.1 microgram per litre for continued exposure.

Spraying of apple orchards is frequently intermittent, but the fact that it may be continued for several days at a time indicates that protective equipment should be used

Air Samples During Tank Filling

Samples of air from the operator's breathing zone were taken in one orchard during tank filling operations. In this case, collected material would be in the form of air-borne dust of parathion concentrate dispersed in the air. Analysis of the samples revealed an average concentration of 1.34 micrograms per litre.

Leaf Samples

Leaf samples were taken for the purpose of determining the concentration of parathion on foliage immediately following spraying, and to determine the rate of decay of the parathion.

About 40 leaves, representing approximately 1000 square centimeters, were picked randomly from two or three adjacent trees, and analyzed for parathion content immediately following spraying. This procedure was repeated at various intervals, using leaves from the same trees for each subsequent test. Leaves from trees which had not been sprayed were analyzed as controls.

Analysis immediately after spraying leaves showed an average concentration of 1130 micrograms per 1000 square centimeters. Subsequent sampling indicated rapid decay of residual parathion during the first 48 hours after spraying followed by a much slower decay rate.

Analysis of air samples taken during leaf sampling under near-windless conditions indicated a low concentration of residual parathion in the air, (0.12 micrograms per litre) within one hour after spraying. Other samples taken when there were light winds blowing showed that even very light winds rapidly reduced air residual concentration to a very low level (within an hour after spraying).

The results of the study indicate that if parathion is applied by concentrate sprayers there is little danger of severe poisoning provided that adequate precautions are taken during handling and use of the insecticides. Any cases of poisoning which were reported were the result of gross negligence and disregard for safety precautions, indicating the need for further education in this respect.

Protective Equipment

Study No. 2—Parathion Residuals on Immature Peaches and the Evironmental Hazards in Spraying and Thinning Operations in Peach Orchards.

Ill effects supposedly attributable to residual parathion during thinning operations in peach orchards in the Niagara district prompted this investigation of residue loss on peach fruit over a 31 day period in 1952. Results of several studies have revealed that while leaf and air residuals rapidly decayed to a safe working level, residues on fruit remained for a much longer time. The data from the following studies have correlated with the results of the above-mentioned study.

Experimental Procedures

Two experimental peach orchard plots were sprayed with parathion 15% wettable powder in concentrations of two pounds per 100 gallons and 1 pound per 100 gallons of water respectively. A third control plot received no spray. Samples of fruit were analyzed for parathion residues at various times throughout the 31 day period.

Results

This field study revealed that for a spray concentration of two pounds of parathion 15% wettable powder per 100 gallons of water the initial residue on immature peaches was 700 micrograms of parathion per 1000 square centimeters of surafce, and the initial decay rate was 42 micrograms per 1000 square centimeters per day. This rapid decay rate continued for 14 days, then decreased markedly. At the termination of the 14 day period the concentration of parathion was approximately 20% (that is 140 micrograms 1000 square centimeters) of the original concentration. For the concentration of 1.5 pounds per 100 gallons of water, now recommended for peach orchards in Canada the equivalent value would be 100 micrograms per 1000 square centimeters.

During hand-thinning operations, workers are exposed to the additional hazard of intoxication from parathion absorption through the skin. To assure protection of workers from this hazard, the Federal Department of Agriculture issued the warning to "avoid handling of sprayed foliage for at least seven days after spraying, and to wear protective clothing from the seventh to the fourteenth day after spraying." As the only reported cases of illness have occurred in workers who ignored the warning, it is concluded that the value of 100 micrograms per 1000 square centimeters represents a safe level of parathion residue on fruit trees.

In the Niagara District, peach orchards are usually sprayed by means of hand-held guns or brooms, with parathion concentrations not exceeding 1.5 pounds 100 gallons of water. Studies on similar equipment employed in apple orchards revealed concentrations of parathion in air ranging from 2 to 15 micrograms per litre. These concentrations so far exceeded the recommended maximum value of 0.1 microgram per litre that, despite the intermittent nature of spraying operations, evidence of marginal intoxication was found. Consequently, protective equipment should be worn during spraying.

Study No. 3—Contamination by Dust Cloud in the Treatment of Vegetable Crops with Parathion

A field study was undertaken at the Federal Department of Agriculture Sub-station at Ste. Clothilde de Chateauguay, Quebec, to assess the hazard of drifting dust during treatment of cabbage with 1% parathion dust.

Samples were collected by five electrostatic precipitators located four feet above ground level (the average breathing height of workers in the field) in a straight line downwind from the duster, at intervals of 50, 100, 200, 300 and 400 feet.

Fresh turnips leaves of known surface area were placed near each precipitator before each trial. They were situated two feet above ground, in order to clear grass and small crops, and yet be low enough to provide a representative sample of cloud deposition on crops. During each trial, which lasted 13 minutes, the crop was dusted at a rate of 40 pounds per acre.

Due to rapid changes in wind velocity and direction, it was impossible to move either the sampling equipment, or the dusting apparatus fast enough to keep the equipment within the dust cloud at all times. Consequently, tests were made only when wind direction

Aerovane Recorder

became relatively constant. This in turn restricted considerably any choice of wind velocity.

During each test, an estimate was made of the percentage of time that the dust cloud enveloped the sampling equipment and the results were adjusted to represent the hypothetical condition in which the dust cloud enveloped the sampling equipment for the entire sampling period.

By the use of the limiting safe value of parathion residue derived in study 2 (that is 100 micrograms per 1000 square centimeters of surface) it is concluded that hazardous surface contamination of crops would extend as far as 290 feet downwind immediately following the 13-minute dusting trial. Estimated distances for dusting periods of 1, 10 and 100 minutes are 72, 275 and 470 feet respectively. Approximately the same limiting distances are arrived at by use of the accepted maximum allowable concentration of parathion residue in foodstuffs and an experimentally determined surface-volume relationship.

The threshold limit for parathion in air has been set at 0.1 micrograms per litre. In this study this air contamination value occurred at a distance of 290 feet downwind from the dusting source.

Experimental Fatigue*

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Everyone, including the layman, is aware of the close relationship between training (adaptation) and resistance to work. This relationship explains why most of the fatigue tests have been found impractical and inefficient when applied to industrial workers. As a matter of fact, workmen in industry are generally well adapted to their work, due to proper selection at hiring time as well as gradual reallocation or elimination of unfit individuals.

An example will show us why the results of fatigue tests, or so called fatigue tests, are so often deceiving, and how cautious one should be in his deductions.

However, some tests can be useful when, after comparison of their respective results, we find that each one can be interpreted in the same way. We will discuss the results obtained with a well known and simple psychomotor test applied to industrial workers.

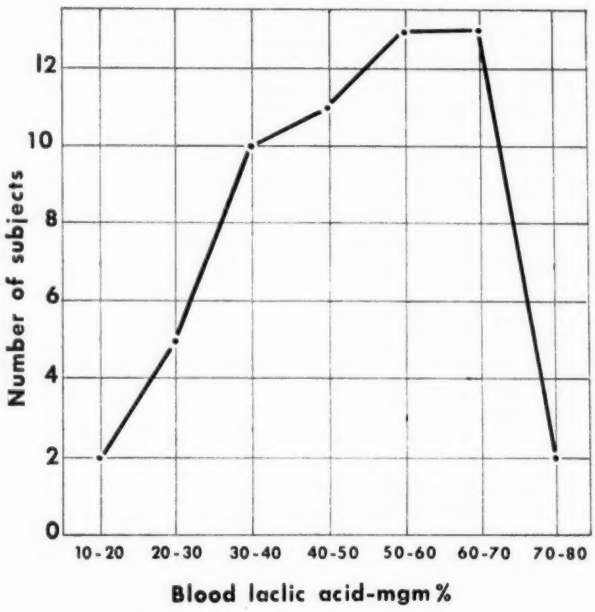
Finally, we will present the results of experiments designed to study part of the underlying mechanism of adaptation and resistance to muscular work.

I. *Blood Lactic Acid Level as a Measure of Fatigue*

The "toxic" theory of fatigue maintains that fatigue results from intoxication by substances accumulated as a result of cellular work. As lactic acid is the normal metabolite of the muscle fibre, its accumulation in blood is frequently referred to as a sign of fatigue.

Let us consider some basic principles of physiology. Lactic acid is normally disposed of by the muscle cell itself, partly by oxidation and partly by reconversion to glycogen. Under conditions of unusual and intense work, the circulatory system is unable to supply sufficient oxygen to support the muscle cell activity and there is a resulting oxygen debt; as a consequence, the lactic acid produced is not completely metabolized and is excreted into the blood stream. During normal body functioning, lactic acid in the blood is reconverted to glycogen and stored in the liver. The level of lactic acid in blood is then the resulting equilibrium of its production and excretion in the muscle and its reconversion to glycogen in the liver. This equilibrium will be influenced by certain physiological characteristics of the individual, such as efficiency of the cardiovascular system in providing the muscles with the necessary oxygen and the capacity of the liver to metabolize lactic acid.

These considerations explain why experiments have shown that the level of lactic acid in blood is a measure of adaptation to work rather than a measure of fatigue. Edwards, Brouha and Johnson (8, 13), Robinson and Harmon (19) found that lactic acid in the blood of an untrained individual was very high after he had performed a certain amount of unaccustomed work. As training progresses, lactic acid decreases gradually to a value slightly over the normal level for a resting man, and this final value may be different from one subject to the other, due to differences in adaptability.



Graph I.

As an example, Graph I shows a frequency distribution of blood lactic acid levels of 57 industrial workers after completion of a rather hard day's work. The highest level observed does not exceed 80 mgm.%; the mean level is 51.1 mgm.% and 84% of the subjects have a blood lactic acid level between 30 and 70

*Paper presented at the annual meeting of the Industrial Medical Association of the Province of Quebec, Quebec City, October 1953.

mgm.%. In a control group of 9 subjects, all office workers, the mean level was 45.7 mgm.%, which is very close to the value obtained in the factory.

In this particular case, the blood lactic acid level was of no help to determine whether fatigue was present or not; on the contrary, the only logical conclusion appeared to be that these workers were well adapted to their work. Such a fatigue test is not very reliable and should be complemented by other observations, particularly a thorough examination of the cardio-vascular system.

This test however could be very useful in certain circumstances, for instance to determine whether or not an individual is fit for a given type of work.

II. *The MacQuarrie Test.*

As we have seen, any fatigue test should be independent of adaptation processes in order to be valid. The importance of ocular reactions to fatigue, as well as their sensitivity, has long been recognized. Let us consider the "flicker frequency" test. Since this is an individual test it is very difficult, for practical reasons, to use it in a study conducted in the factory.

For this reason we decided to use a test which included the ocular element and at the same time could be used collectively. The "MacQuarrie Test for Mechanical Ability" appeared to possess these characteristics, and to our knowledge it had never been used to determine fatigue. This test, comprising seven different sub-tests, was devised by MacQuarrie for the purpose of investigating hand dexterity, and was distributed by the California Test Bureau for use in selection of employees for work requiring a certain degree of manual dexterity. For this experiment we selected the first three sub-tests because they employed the simplest physical elements of eye-hand co-ordination. In the other four sub-tests, the psychological element is more prominent.

As shown in figure I, the first sub-test consists of drawing a continuous line through the series of interrupted lines without touching them; the second in placing three dots in each circle as rapidly as possible; the third in placing one dot in each of the irregularly spaced circles. The alloted time for each sub-test is limited and always the same. The score is then calculated as the total number of trials minus the number of errors or unsuccessful items.

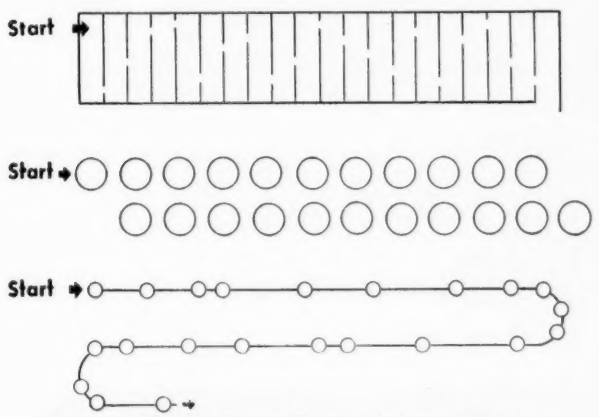


Figure 1. —The MacQuarrie Test for Mechanical Ability, Sub-tests 1, 2 and 3.

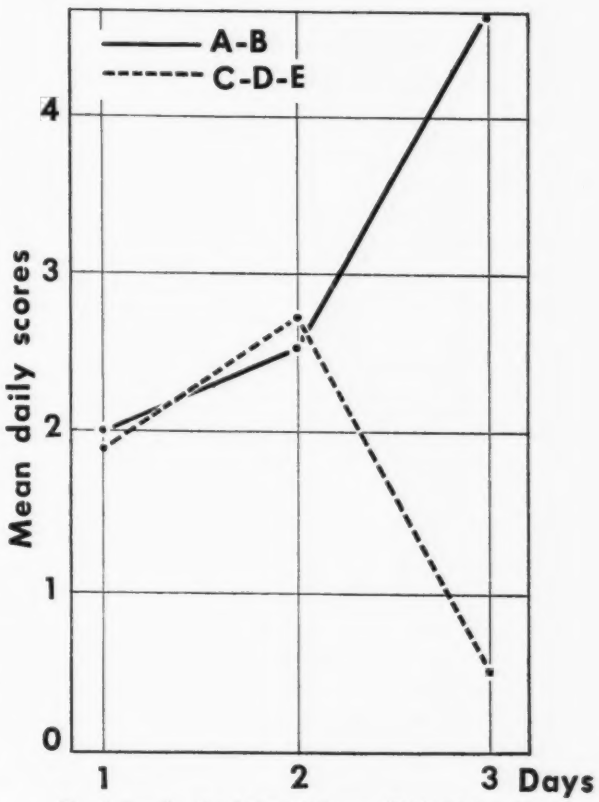
This test was applied to 20 industrial workers employed at the same type of work. This was team work and the subjects were distributed as follows:

2 teams, A and B, each composed of 7 men;

3 teams, C, D and E, each composed of 5 men.

The test was applied at the beginning and at the end of the day's work, always in the same room and under the supervision of the same person; all the copies were examined and the scores computed by the same individual. The negative or positive differences between the morning and the night scores were called the daily gain and the results attained by the different teams (5 and 7 men) were compared.

For A and B teams, there was a steady gain from the first to the third day, the third day gain being the only one statistically significant when compared to the



Graph 2. —Results of test with teams of industrial workers.

Results

The results, shown on graph 2, were analyzed statistically by the Student-Fisher method.

first day score; the difference was 2.64 ± 1.11, the "t" value 2.38, and the "p" value smaller than 0.05.

For C, D and E teams, the gain for the second day was higher than the gain for the first day, but the difference is not significant. The third day gain, showed a decrease of 1.4 when compared to the first day; the difference however is not significant.

If we compare the 5 man to the 7 man teams, we find a difference of 4.1 between the respective gains of the third day, with a "t" value of 2.57 and "p" value smaller than 0.25. This difference is therefore statistically significant.

Discussion and Conclusion.

Without discussing the mathematical justification of statistical analysis, let us say that such a treatment of experimental data makes interpretation of these data possible but it is difficult to say whether or not the observed difference is due to chance or is a result of changes in experimental conditions.

Since the third day difference in gain between the 5 and 7 men teams is statistically significant, it is assumed that it might be due to the change in experimental conditions, in this instance the number of men in each team.

However, it is much too soon to determine the exact value of this test as a measure of physiological fatigue, and one should be very cautious in this respect. It is interesting to note that other tests such as the Donaggio reaction, arterial tension and cardiac frequency measurements, performed at the same time, all have given similar results which, although not statistically significant, show a definite trend when the same method of interpretation is used. We hope that this study will open the way to this approach to the problem of industrial fatigue. If new data could be supplied which would prove the real value of this test, we would have a very useful criterion, because of its simplicity and easy application.

III. *Experimental Work*

The problems of adaptation to work and physiological fatigue have always been a challenge to physiologists, when transposed from the laboratory to the factory. A better and more complete understanding of the physiological mechanism of adaptation and resistance to muscular work would be a great help in solving problems of human fatigue. We decided to do some experimentation with the purpose of adding to this understanding.

Over the past few years, numerous people (1, 4, 5, 6, 7, 9, 10, 12, 14, 17, 19, 21, 22) in various ways have stressed the importance of the cortico-adrenal hormones in muscular work. Other authors (2, 3, 11, 15, 21) have dwelt on the influence of ascorbic acid on resistance to fatigue from muscular exercise. On the other hand, results obtained in our laboratory point to a close relationship between the cortico-adrenal function and the tissue level of ascorbic acid.

The present investigation was designed to test the hypothesis that ascorbic acid administration has a beneficial effect during adaptation to muscular work.

Male albino rats of the Wistar strain were used. Some of them were given three daily oral doses of 50 mgm. of ascorbic acid; untreated animals were used as controls. The exercise consisted of running in revolving drums rotating at 15 r.p.m. Two series of experiments were carried out. In the first one, two groups of animals, as described above, I (controls) and I-A (Ascorbic acid treated) were trained to run 1200 turns twice daily, by progressively increasing the number of turns from 100 turns twice a day, until the desired level of training was reached. The training period for this group was 5½ weeks. In the second series, two other groups of rats were used, II (controls) and IIA (ascorbic acid treated) and the same level of training for these groups was reached in two weeks. At the end of the training periods, all animals were subjected to a resistance test. For this purpose, they were put back into the revolving cages and compelled to run until completely exhausted. The total number of turns the animals were able to run represented their resistance to work. After this final test, the animals were sacrificed. The thymus and adrenals were removed, carefully dissected and weighed. In the second series of experiments, the adrenals were also analyzed for their succinic dehydrogenase (S.D.) activity, either expressed as the total activity for both glands or the activity for 100 mg. of adrenal wet weight.

Table 1. — Effect of Ascorbic Acid on Adrenal Function During Muscular Work

Treatment	Number of rats	Thymus W. mgm.	ADRENALS			Resistance 103 turns
			W. mgm.	S.D. Tot.	S.D. % mgm.	
I	10	354.4	40.3	...	...	4.9
IA	9	305.8	41.4	...	...	6.2
% difference		—13.7	+2.66	...	...	+26.5*
II	19	304.8	37.6	120.0	317.6	8.3
IIA	21	257.5	36.9	97.9	276.6	9.3
% difference		—15.5*	—1.90	—18.4*	12.9	+12.0

* Difference statistically significant.

S.D. —Dehydrogenase activity expressed as mgm. of reduced hydrogen acceptor.

Normal dehydrogenase activity (20 rats): tot.: 95.3 — W: 245.4

Results

The results are shown in Table I. In the two series of experiments, the animals given ascorbic acid showed an increase in resistance and a greater decrease in thymus weight. In the second series of experiments, the adrenals of treated animals (IIA) show an oxidative

(Continued on page 26)

Resistance and Acclimatizing to Cold

At Laval University, Quebec, a series of animal experiments has been conducted, under the direction of Dr. L. P. Dugal, Director and Professor, Department of Experimental Physiology, School of Medicine, for the purpose of investigating possible differences in the ability of animals to resist cold or become acclimatized to it when fed equi-vitaminic and equi-caloric diets.

The self selection of food by the animals was used as a means of determining the most satisfactory diet during exposure to cold. The criteria for the best diet were survival and growth.

In the first experiment, rats were the experimental animals used. The first period of exposure to sudden cold, during which time all animals lose weight, was designated as the period of resistance and the criterion used was percentage of survival; the period of acclimatization started when those rats which had survived began to gain weight, and they were considered to be acclimatized when they had regained their pre-exposure weight.

Two types of diet, one rich in fat, the other rich in carbohydrates, were fed to two groups of one hundred rats each, respectively, and after 16 days of exposure, survival was 85% for the group on the high fat diet, and 40% for the group on the carbohydrate diet. These results showed that the high fat diet was decidedly superior to the high carbohydrate diet in terms of resistance and acclimatization to cold. But all of the animals which had succumbed showed symptoms of some nutritional deficiency. The only nutritional deficiency in the diet was ascorbic acid, but the rat is able to synthesize this substance. Further experiments indicated that ascorbic acid production increased gradually to a high level in the tissues of rats which became acclimatized. Rats which succumbed had a very low tissue content of this vitamin.

Caloric intake also increased from 70 calories per day at room temperature to 100 calories per day in cold rooms.

A few experiments were carried out in which ascorbic acid was added to the diet of rats exposed to cold and the results showed that ascorbic acid did increase the resistance of rats to cold, as measured by percentage of survival. This stimulated research on the effects of Vitamin C on the resistance to cold of animals such as guinea pigs and monkeys, which are unable to synthesize this vitamin.

From experiments involving more than 1,000 guinea pigs it was found that, in order to survive and become acclimatized, these animals required increased amounts of ascorbic acid with decreases in temperature of the environment. It was also revealed that there was greater retention of the vitamin in the tissues, especially the adrenals, at low temperatures than at normal room temperature. As with the rat, guinea pigs which failed to acclimatize showed a decrease in ascorbic acid content of the adrenals. In this experiment, ascorbic acid was administered by mouth to all experimental animals for at least three weeks before exposure to cold.

In order to discover whether ascorbic acid exercised the same beneficial effects on larger animals, a series of experiments was performed with Rhesus monkeys as experimental animals.

The criterion for determining the degree of resistance of monkeys was the ability of the animal to maintain rectal and intra-muscular temperatures during a two-hour exposure to –20° centigrade, temperature being measured with thermocouples. Incidence of frost bite in the tails of all monkeys was also determined.

In the first experiment, 24 monkeys were divided into three groups: Group I, consisting of 11 monkeys, was kept constantly at room temperature before exposure and fed Purina Dog Chow, plus a supplement of 25milligrams of ascorbic acid by mouth daily; Group 2, 8 monkeys, received the same amount of food and ascorbic acid per day as Group 1, but was kept in an environment of 10° centigrade for six months prior to exposure to –20° C; Group 3, consisting of 5 monkeys was treated the same as Group 2, except that the monkeys received 325 milligrams of Vitamin C daily.

For exposure to intense cold (–20° centigrade), the monkeys were immobilized in wooden boxes, with fingers and toes protected from frost-bite by mittens, but with tails unprotected. Rectal and intramuscular thermocouples were so arranged that direct temperature readings would register on a galvanometer kept at room temperature, and cold room temperature and humidity were kept constant at –20° centigrade and 60% respectively.

Throughout this experiment, there was a fall in rectal and intramuscular temperatures of all groups during exposure, but the fall for Group 3, was considerably less than for Groups 1 and 2, which were not significantly different.

Animals in Groups 1 and 2 suffered more frequently from frost-bite of the tail than those of the other group.

The results just described were based on comparisons between groups. The results obtained in a second experiment, when comparing the different treatments, as described above, on the same individuals, were the same as those obtained when comparing the resistance of the different groups. Finally, a third experiment showed that large doses of ascorbic acid increase tolerance to intense cold even for monkeys not pre-exposed to mild cold, but significantly less than for monkeys already exposed to a mild environment.

The investigators conclude that ascorbic acid appears to be very important for the resistance and acclimatization to cold, at least in animals.

EXPERIMENTAL FATIGUE

(Continued from page 24)

activity (S.D.) very close to normal, while adrenals from non-treated animals have S.D. values significantly higher. The adrenal weight was almost the same in both groups from each series.

Discussion and Conclusion

These results would indicate an increase in peripheral effectiveness of cortical hormones in animals treated with ascorbic acid, as can be deduced from the greater decrease in thymus weight and the increase in resistance to work. On the other hand, if the adrenals of treated animals have been as active as those of the controls, it appears that the total work of the adrenals was much less in the treated animals, since their actual oxidative activity at the removal time was almost back to normal. Hence we could say that ascorbic acid administration, while enhancing adaptation and resistance to work, and increasing the effectiveness of corticoadrenal hormones, decreases the total work of the adrenal glands.

General Conclusion

We wish to apologize for the preliminary character of the observations presented here. One purpose of this paper was to emphasize the necessity as well as the possibility of working simultaneously on the practical and the fundamental aspects of physiological problems such as the physiology of fatigue. The following are some observations made on industrial workers in an attempt to check the application of the conclusions obtained in our experimental work. To a group of workers, we administered orally 250 mgm. of ascorbic acid daily from mid-November 1952 to mid-April 1953; untreated subjects served as controls. Unfortunately, due to lack of objectivity in the criteria used for testing the effectiveness of the treatment, the results were rather deceiving. However, we observed a decrease in the duration of common cold in treated subjects, although the frequency was the same in both groups. At the same time, the treated subjects reported an increase in their subjective feeling of well being. We made no attempt to analyze these results further, until other and better observations could be made.

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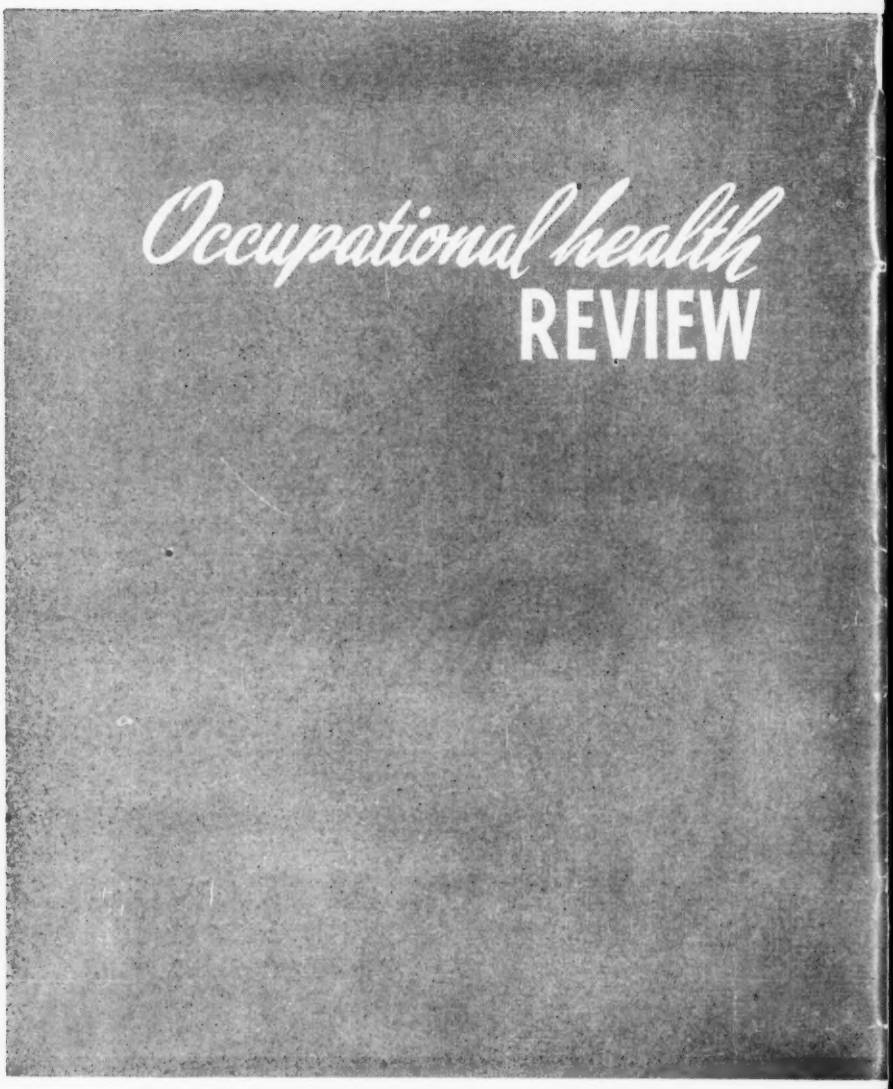
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